

## **Detection and Classification of Baleen Whale Vocalizations from Autonomous Platforms**

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### **LONG-TERM GOALS**

Our long-range objective is to understand the oceanographic processes that influence the distribution of whales in the ocean. In support of this objective we seek to develop new techniques and technologies that enable us to relate the occurrence and movement of animals to physical, biological, and possibly anthropogenic forcing mechanisms over long time scales. This work will ultimately improve our ability to predict whale distribution and bolster efforts to mitigate human impacts on marine mammals.

### **OBJECTIVES**

Our research has three specific objectives:

1. Develop a platform-independent modular acoustic package capable of automated detection and classification of whale vocalizations and suitable for use on a variety of autonomous platforms.
2. Characterize the efficacy of several automated detector algorithms using a rich set of collocated visual and acoustic measurements collected in 2006 and 2007.
3. Perform quantitative field trials to evaluate baleen whale detection performance in the context of other visual, acoustic, and environmental observations.

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## **APPROACH**

Almost all mitigation efforts rely on a comprehensive understanding of whale distribution to effectively separate human activities from baleen whales. This understanding is incomplete, however, and further research is needed to elucidate the environmental factors that govern baleen whale distribution.

Marine mammal distribution has traditionally been studied using visual surveys where human observers detect, identify, and count animals at the sea surface. These methods require adequate sighting conditions: daylight, good visibility, and low sea state. When conditions deteriorate, such as at night or in fog or heavy seas, detecting *any* marine mammals at the surface becomes difficult if not impossible. Conducting ship or aerial surveys for periods of weeks with many observers is both expensive and inefficient, since the observers search for marine mammals only during adequate sighting conditions and are idle during poor conditions. In contrast to visual surveys, passive acoustic detection can occur continuously (24 hours a day) in any weather conditions over weeks to months. However, most acoustic recorders used for marine mammal studies are moored and, except for very-low-frequency applications (e.g. blue whales), are limited to monitoring the area immediately surrounding the recorder.

Many of the limitations of both visual surveys and moored acoustic systems can be overcome by incorporating a passive acoustic monitoring capability on autonomous platforms. Ocean gliders and profiling drifters, in particular, have characteristics that are very well suited for passive acoustic monitoring: silent operation, long endurance (>1 month), and robust near-real-time satellite and/or radio communications. Gliders and profiling drifters offer a suite of oceanographic sensors that can be used in association with acoustic data to characterize marine mammal habitat. These sensors provide measurements that are comparable to or, in some cases, better than the measurements collected during modern, ship-based, marine mammal habitat studies.

## **WORK COMPLETED**

WHOI Student Fellow Sarah Mussoline, under the direction of Mark Baumgartner, isolated all baleen whale calls in 154 hours of acoustic data collected from an array of moored passive acoustic recorders deployed during 2006 and 2007. This dataset, along with 70 hours of collocated visual survey effort, is being used to validate detectors for right, sei, and humpback whales.

## **RESULTS**

Two significant papers have been published (see below) including the first published account of the use of autonomous vehicles for the study of marine mammal ecology. This paper, appearing in a special volume of *Limnology and Oceanography*, summarizes new findings about sei whale vocalizations and feeding behavior inferred from glider operations in Great South Channel during May 2005.

A second paper, published in the *Journal of the Acoustical Society of America*, attributes a common low-frequency down sweep call to sei whales and describes an automatic detector for this call. A novel detector/classifier design involving automated pitch tracking and linear discriminant function analysis has been developed (Figures 1, 2). This will be the first baleen whale detector implemented on the new WHOI DMON instrument (see Related Projects, below). We will initially validate

performance of this detector during DMON bench testing using previously recorded/isolated/validated sei whale calls.

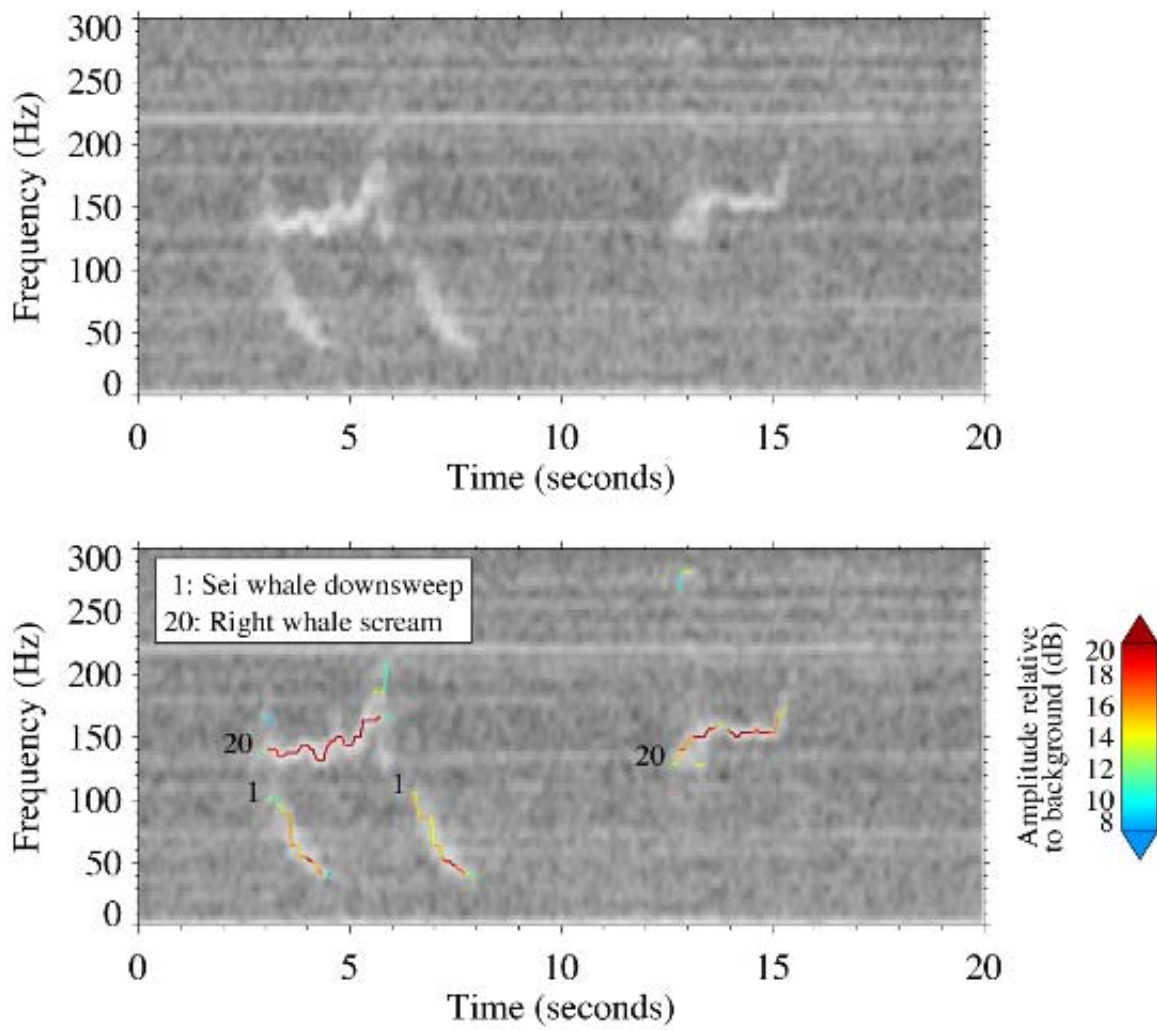
## **RELATED PROJECTS**

This project has largely merged with a parallel WHOI effort to develop new broadband acoustic hardware and the accompanying software for automated detection and classification: “Development and Validation of a Mobile, Autonomous , Broadband Passive Acoustic Monitoring System for Marine Mammals” with PI’s Fratantoni, Baumgartner, and Johnson. Rather than developing a stand-alone low-frequency detector package as initially proposed, our baleen whale detector algorithms will be implemented in real-time on the DMON, a low-power self-contained acoustic signal processing device developed at Woods Hole Oceanographic Institution (WHOI). This device has been created specifically for passive acoustic detection and so has the necessary broadband, low-noise signal acquisition capabilities. The device will be integrated in profiling floats and gliders to create a persistent detection capability. As detection algorithms mature, they will be ported to the DMON for autonomous operation.

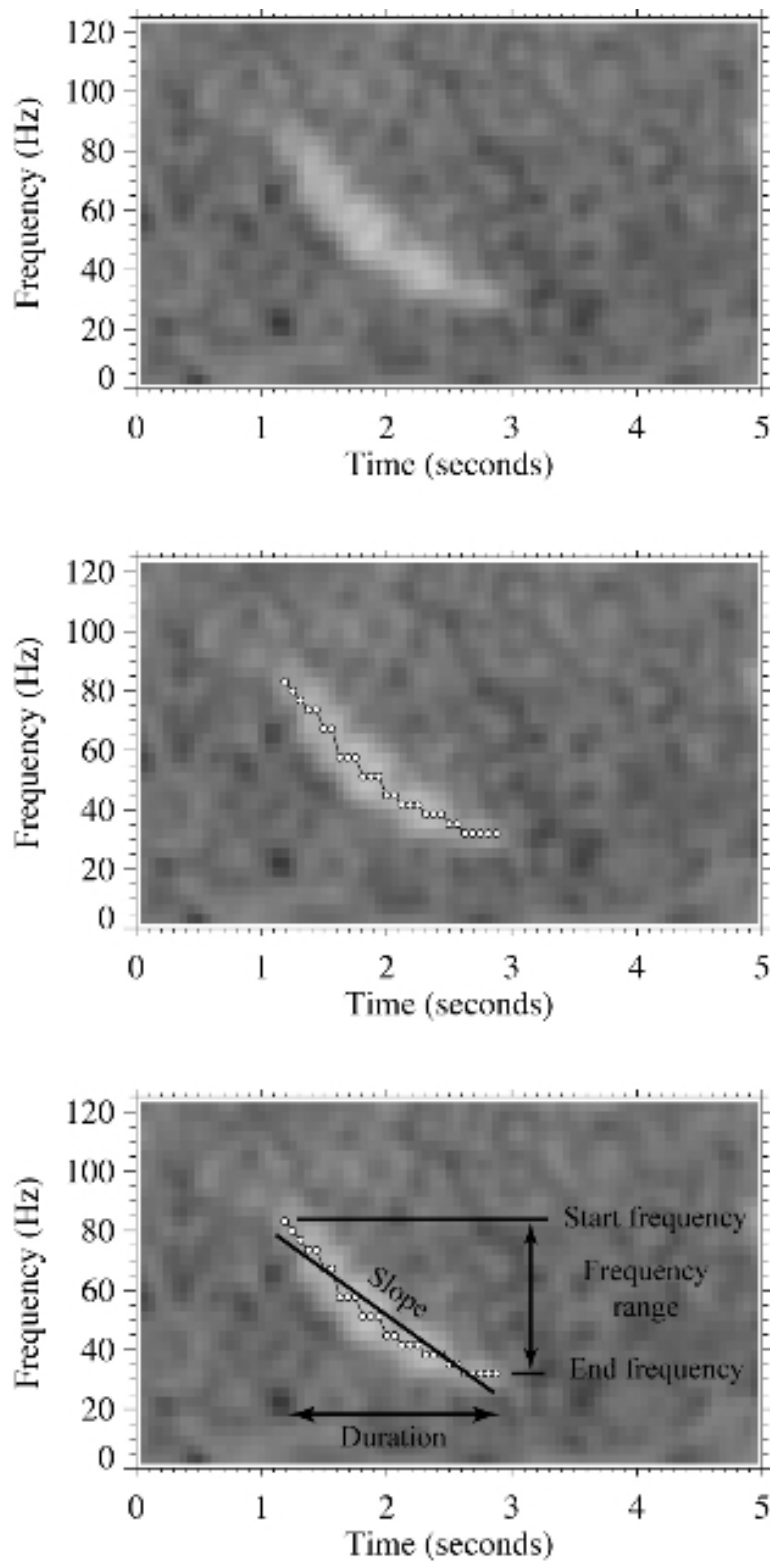
## **PUBLICATIONS**

Baumgartner, M. F. and D. M. Fratantoni. 2008. Diel periodicity in both sei whale vocalization rates and the vertical migration of their copepod prey observed from ocean gliders. *Limnology and Oceanography* 53: 2197-2209.

Baumgartner, M. F., S. M. Van Parijs, F. W. Wenzel, C. J. Tremblay, H. C. Esch, and A. M. Warde. 2008. Low frequency vocalizations attributed to sei whales (*Balaenoptera borealis*). *Journal of the Acoustical Society of America* 124:1339-1349.



*Figure 1: Spectrogram illustrating the results of the pitch tracking algorithm and classification of two simultaneous but distinct baleen whale vocalizations: a sei whale downsweep, and a right whale scream.*



**Figure 2:** Spectrogram illustrating the pitch tracking results for a sei whale downsweep. The lower panel depicts several of the attributes that are automatically extracted and used in a linear discriminant function analysis.